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Comparative Water Quality Indices of Hand-Dug Wells Near Septic Tanks In Effurun, Delta State, Nigeria

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Abstract: *As water is vital for the continuous survival of life on the planet earth, hand-dug wells are the cheapest alternatives to pipe born or borehole water in developing countries. This study was aimed at calculating and comparing the Water Quality Indices (WQI) of water from hand-dug wells cited near septic tanks in order to determine its suitability for drinking purposes using the Weighted Arithmetic Water Quality Index (WAWQI) and Canadian Council of Ministers of the Environment (CCME) Water Quality Index (CCME WQI). The calculation using the WAWQI revealed Well A (81) = "Very poor", Well B (58) = "Poor", Well C (63) = "Poor", and Well D (95) = "Very Poor" water qualities; whereas using CCME WQI calculations revealed Well A (57) = "Marginal", Well B (58) ="Marginal", Well C (58) = "Marginal" and Well D (35) = "Poor" water qualities. Conclusively, the two different calculation methods revealed different water quality indices for the same wells locations, but with nearly similar interpretations on their respective scales. The two calculations methods revealed water quality that is unfit for drinking, which could be as a result of contamination from the septic tanks near the wells. Water from all the wells need to be treated before drinking.*

Keywords: *Waters, Quality, Index, Groundwater, Hand-Dug, Wells*

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I. Introduction

As water is vital for the continuous survival of life on the planet earth, hand-dug wells are the cheapest alternatives to pipe born or borehole water in developing countries.

Water quality index is a simple and efficacious tool used in assessing water quality for its suitability for various purposes [1]. Water quality index provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters. The objective of the water index is to turn complex water quality data into information that is understandable and usable by the public. A single number cannot tell the whole story of the water quality; there are many other water quality parameters that are not included in the index. However, a water quality index based on some very important parameters can provide a simple indicator of water quality. In general, water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of a water body with number [2].

According to [3], site-specific conditions and local groundwater flow are often ignored when installing septic systems and wells. In areas with small lots (thus high spatial septic system densities), shallow domestic wells are prone to contamination by septic system leachate. Septic systems can contaminate ground water with dissolved solids, nitrate, anoxic constituents (manganese, iron and hydrogen sulfide), organic compounds, and microorganisms. There is a widespread misperception that nitrate is a universal indicator of ground-water contamination by sewage [4]. Sewage is the primary source of pathogenic microbial contamination of ground water as it is in surface water. The situation of sewage contamination is worsening due to the unsafe method of sewage system construction and the shallow depth of water table. Wastewater in rural areas of Upper Egypt is disposed and collected into an underground sewage room. The shallow depth of hand pumps and high capacity of wells is likely to create a susceptible condition of rural water supply [5]. Physico-chemical and Biological parameters present in water under investigations are used to compute water quality index. The measured content of the pollutant, ideal content and standard content for safe use determine this water quality index. Whereas the ideal content and measured one are fixed for a sample, the standard content varies from country to country and from agency to agency. Thus, WQI arrived at by using different standards may vary, if the standard values differ. Presently measured results and standard values of different countries / agencies yield drastically varying WQI in some cases in present measurements [6].

This study was aimed at calculating and comparing the Water Quality Indices (WQI) of water from hand-dug wells cited near septic tanks in order to determine its suitability for drinking purposes using the

Weighted Arithmetic Water Quality Index (WAWQI) and Canadian Council of Ministers of the Environment (CCME) Water Quality Index (CCME WQI).

II. Materials And Methods

Methodology for the Determination of Physico-chemical parameters

The methods described in [7] in conjunction with Guidelines for drinking-water quality second edition volume 3 [8] were used in the analysis of physico-chemical parameters.

Calculation Method I: Weighted Arithmetic Water Quality Index Method (WAWQI)

The water quality index was calculated using the World Health Organizations (WHO) standards in conjunctions with the weighted arithmetic index method [9]. The quality sub index (q_n) was calculated using the equation below;

$$q_n = \frac{100[V_n - V_{io}]}{[S_n - V_{io}]} \quad (1)$$

Where V_n = Estimated value of the n^{th} parameter of the given sampling station.

V_{io} = Ideal value of n^{th} parameter in pure water (this value is 0 for all other parameters except the parameter pH and Dissolved oxygen (7.0 and 14.6 mg/L respectively).

And S_n = Standard permissible value of the n^{th} parameter.

To calculate unit weight for the nth parameters,

$$W_n = \frac{K}{S_n} \quad (2)$$

Where K, is the proportionality constant which can be calculated using formula

$$K = \frac{1}{\frac{1}{\sum_i^n S_i}} \quad (3)$$

Where S_i is standard permissible value for nth parameter

Then the Water Quality Index (WQI) is calculated using

$$WQI = \frac{\sum(W_n \times q_n)}{\sum W_n} \quad (4)$$

Table I: Water Quality Index (WQI) and Status of Water Quality

0-25	Excellent Water Quality
26-50	Good Water Quality
51-75	Poor Water Quality
76-100	Very Poor Water Quality
>100	Unsuitable for Drinking

Source: [10]

Calculation Method II: Canadian Council of Ministers of the Environment (CCME) Water Quality Index Formulation [11]

The index consists of three factors:

F_1 (**Scope**) represents the extent of water quality guideline non-compliance over the time period of interest. It has been adopted directly from the British Columbia Index:

$$F_1 = \left(\frac{Number\ \ of\ failed\ \ variables}{Total\ \ number\ \ of\ variables}\right) \times 100 \quad (5)$$

Where, **variables** indicate those water quality variables with objectives which were tested during the time period for the index calculation.

F_2 (**Frequency**) represents the percentage of individual tests that do not meet objectives (“failed tests”):

$$F_2 = \left(\frac{Number\ \ of\ failed\ \ tests}{Total\ \ number\ \ of\ tests}\right) \times 100 \quad (6)$$

The formulation of this factor is drawn directly from the British Columbia Water Quality Index.

F_3 (**Amplitude**) represents the amount by which failed test values do not meet their objectives. F_3 is calculated in three steps.

(i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an “excursion” and is expressed as follows. When the test value must not exceed the objective:

$$excursion_i = \left(\frac{Failed\ \ Test\ Value}{Objective_{\ j}}\right) - 1 \quad (7)$$

For the cases in which the test value must not fall below the objective:

$$excursion_i = \left(\frac{Objective_{\ j}}{Failed\ \ Test\ Value}\right) - 1 \quad (8)$$

(ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or *nse*, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{Number\ of\ Tests} \quad (9)$$

iii) F_3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right) \quad (10)$$

The CCME WQI is then calculated as:

$$CCME\ WQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \quad (11)$$

The factor of 1.732 arises because each of the three individual index factors can range as high as 100. This means that the vector length can reach $\sqrt{100^2 + 100^2 + 100^2}$ =$\sqrt{30000}$ =173.20508 as a maximum. Division by 1.732 brings the vector length down to 100 as a maximum.

Once the CCME WQI value has been determined, water quality can be ranked by relating it to one of the following categories:

Excellent: (CCME WQI Value 95-100) – water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.

Good: (CCME WQI Value 80-94) – water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

Fair: (CCME WQI Value 65-79) – water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Marginal: (CCME WQI Value 45-64) – water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.

Poor: (CCME WQI Value 0-44) – water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

III. Results And Discussion

Table II: Computation of Arithmetic Water Quality Index of Well A

S/N	Parameters	Well A	WHO Standards Values (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	5.8	8.5	0.3635	80.00	29.0805
2	Total Dissolved Solid (mg/l)	275.0	500	0.0062	55.00	0.3399
3	Conductivity (µs/cm)	430.0	250	0.0124	172.00	2.1258
4	Turbidity (NTU)	4.0	5	0.6180	80.00	49.4368
			K = 3.0898	$\sum W_n$ **=1.0000**		$\sum(W_n \times qn)$**=80.9829**

Using equation (4), For Well A, WAWQI is **80.983**

Table III: Computation of Arithmetic Water Quality Index of Well B

S/N	Parameters	Well B	WHO Standards Values (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	6.2	8.5	0.3635	53.33	19.3858
2	Total Dissolved Solid (mg/l)	217.6	500	0.0062	43.52	0.2689
3	Conductivity (µs/cm)	340.0	250	0.0124	136.00	1.6809
4	Turbidity (NTU)	3.0	5	0.6180	60.00	37.0776
			K = 3.0898	$\sum W_n$ **=1.0000**		$\sum(W_n \times q_n)$ **=58.4132**

Using equation (4), **For Well B, WAWQI is 58**

Table IV: Computation of Arithmetic Water Quality Index of Well C

S/N	Parameters	Well C	WHO Standards Values (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	pH	5.5	8.5	0.3635	100.00	36.3506
2	Total Dissolved Solid (mg/l)	204.8	500	0.0062	40.96	0.2531
3	Conductivity (µs/cm)	320.0	250	0.0 124	128.00	1.5820
4	Turbidity (NTU)	2.0	5	0.6180	40.00	24.7184
			K = 3.0898	$\sum W_n$ **=1.0000**		$\sum(W_n \times qn)$**=62.9041**

Using equation (4), **For Well C, WAWQI is 63**

Table V: Computation of Arithmetic Water Quality Index of Well D

S/N	Parameters	Well D	WHO Standards Values (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	W_nq_n
1	Ph	6.3	8.5	0.3635	46.67	16.9648
2	Total Dissolved Solid (mg/l)	435.2	500	0.0062	87.04	0.5379
3	Conductivity (□ s/cm)	680.0	250	0.0124	272.00	3.3617
4	Turbidity	6.0	5	0.6180	120.00	74.1552
			K = 3.0898	$\sum W_n$ **=1.0000**		$\sum(W_n \times qn)$**=95.0196**

Using equation (4), **For Well D, WAWQI is 95**

Table VI: Computation of CCME Water Quality Index of Well A - D

	F_1	F_2	F_3	F_1^2	F_2^2	F_3^2		$\sqrt{F_1^2+F_2^2+F_3^2}$	$\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}$	CCME WQI
Well A	50	50	22.86	2500	2500	522.58	5522.58	74.31	42.91	57
Well B	50	50	15.45	2500	2500	238.70	5238.70	72.38	41.79	58
Well C	50	50	17.11	2500	2500	292.75	5292.75	72.75	42.00	58
Well D	75	75	36.20	5625	5625	1310.44	12560.44	112.07	64.71	35

Table VII: Comparative Analysis of Arithmetic and CCME Water Quality Indices

Samples	WAWQI	Quality Status	CCME WQI	Quality Ranking	Distance from Septic Tank (m)
Well A	81	Very Poor Water Quality	57	Marginal	9.30
Well B	58	Poor Water Quality	58	Marginal	6.90
Well C	63	Poor Water Quality	58	Marginal	7.80
Well D	95	Very Poor Water Quality	35	Poor	5.70

Table VII above shows the calculated arithmetic water quality index and the CCME water quality index and the corresponding classification of the water quality. The results show high values of WAWQI in Well-A (81) and Well-D (95); and as a result (Very poor water quality). But the same Well-A revealed Marginal water quality and Well-D revealed poor water quality on CCME scale. Wells B and C indicated (poor water quality) on the WAWQI scale, but revealed marginal water quality on the CCME scale for both Wells B and C. It is evident, that the two different calculation methods revealed different water quality indices for the same locations, but with nearly similar interpretations on their respective scales as in Well-D, which revealed very poor and poor water quality using WAWQI and CCME WQI respectively. And Well D was the closest to septic tank at a distance of 5.7 m.

Both calculations revealed water quality that is unfit for drinking, frequently threatened or impaired; conditions often depart from natural or desirable levels, which could be as a result of contamination from the septic tanks near the wells.

IV. Conclusion

Conclusively, the two different calculation methods revealed different water quality indices for the same wells locations, but with nearly similar interpretations on their respective scales. The two calculations methods revealed water quality that is unfit for drinking, which could be as a result of contamination from the septic tanks near the wells.

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